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Comparison of Conventional Linted Cottonseed and Mechanically Delinted Cottonseed in Diets for Dairy Cows*

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ABSTRACT

Performance of lactating dairy cows fed diets containing either mechanically delinted whole cottonseed (DWCS; 3.7% lint) or linted whole cottonseed (LWCS; 11.7% lint) was measured. Forty primiparous (86 ± 39 d in milk) and 40 multiparous (88 ± 30 d in milk) cows were fed a total mixed ration containing 13% (dry matter basis) DWCS or LWCS in two blocks of 112 d (n = 53 and 27, respectively). Other total mixed ration ingredients (dry matter basis) were corn silage (28.1%), alfalfa silage (23%), high moisture shelled corn (27.8%), soybean meal (1.8%), expeller soybean meal (1.8%), blood meal (2%), and mineral-vitamin supplements (2.5%). Dry matter intake and milk yield were measured daily and milk composition every other week. Fecal grab samples were taken during wk 3 and 13 of each block to estimate excretion of intact whole cottonseeds. Milk yield, 3.5% fat-corrected milk, energy-corrected milk, milk composition and dry matter intake were not affected by whole cottonseed source. Body condition score tended to increase more with DWCS (0.22 vs. 0.11) for primiparous cows, although this was not reflected in body weight change. Dry matter digestibilities, based on indigestible ADF, were 63.5 and 64.8% for the DWCS and LWCS diets. It was calculated that 2.5 and 1.5% of the consumed seeds were excreted as whole cottonseeds in feces with the DWCS and LWCS diets, respectively. Although statistically significant, treatment differences in the proportion of intact seeds in the fecal DM would have little nutritional consequence. Mechanically delinted WCS performed as well as LWCS for all of the cow performance and milk composition variables measured.

(**Key words:** cottonseed, mechanically delinted, dairy cow)

Abbreviation key: DWCS = delinted whole cottonseed; **LWCS** = linted whole cottonseed; **WCS** = whole cottonseed.

INTRODUCTION

Whole cottonseed (**WCS**) is a unique feedstuff because of its high content of energy, mainly in the form of oil, moderately high level of CP, and high quality fiber (Clark and Armentano, 1993; Adams et al., 1995; Abel-Caines et al., 1997; Harvatine et al., 2002a, 2002b).

The fiber in WCS resides largely in the lint and hulls that cover the seed. Linters (lint) are short cotton strands that remain attached to the cottonseeds after ginning, and represent about 10 to 12% of total weight in conventional linted cottonseed. Composed mostly of cellulose, lint is very digestible in the rumen (Palmquist, 1995). Lint is also a highly desired commodity for the manufacture of a myriad of products, varying from absorbent cotton and medical pads to nutritional supplements for humans and rocket propellants. Because of demand for lint for other uses, an increased supply of delinted cottonseed (**DWCS**) may be available for use as a dairy feed. Two methods are used for removal of lint from the seed, depending on future applications and are referred to as chemical (acid) or mechanical delinting (Smith and Cothren, 1999).

Although contributing to fiber effectiveness in the rumen, lint increases bulkiness and makes it difficult to mechanically handle linted whole cottonseed (**LWCS**). Many approaches have been explored for improving handling and nutritional value of LWCS, including cracking, grinding, pelleting, heating, extruding, coating with starch, use of lint-free cottonseed (Pima), or acid delinted cottonseed (Coppock et al., 1985; Pena et al., 1986; Bernard and Calhoun, 1997; Bernard, 1999; Bernard et al. 1999; Noftsger et al., 2000; Santos et al., 2002).

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The objective of this experiment was to evaluate the effect of feeding mechanically delinted whole cottonseed on performance and excretion of intact seeds by lactating dairy cows.

MATERIALS AND METHODS

Animals and Management

Eighty cows (40 multiparous and 40 primiparous) were used in two blocks over time because of limitations on barn space and cow availability. Each block lasted for 126 d, including 14 d for a pretrial period and 112 d for the experimental period. Block I began on February 14, 2002, and finished on June 19, 2002, and included 26 primiparous and 27 multiparous cows. During the last week of the pretrial period, primiparous cows averaged (± SD) 32.5 ± 4.1 kg/d of milk and 89 ± 37 DIM, and multiparous cows 42.5 ± 6.2 kg/d of milk and 76 ± 23 DIM. Block II started on April 19, 2002, and lasted until August 22, 2002, with 14 primiparous and 13 multiparous cows. During the last week of the pretrial period, primiparous cows averaged 35.7 ± 3.1 kg/d milk and 82 ± 42 DIM, and multiparous cows 41.8 ± 6.2 kg/d and 113 ± 44 DIM. Animals were housed in a tie-stall barn, were fed individually once daily in the morning, and were milked twice daily (0400 and 1600 h).

Cows were blocked by parity and paired based on DIM and a 7-d average milk yield during the pretrial period 3 d before the beginning of the experimental period. Cows from each pair were randomly assigned to one of the two treatments.

This experiment was conducted at the USDA-ARS US Dairy Forage Research Center Experimental Farm, located in Prairie du Sac, Wisconsin, after the protocol was approved by the Animal Use Committee of the College of Agricultural and Life Sciences, University of Wisconsin-Madison.

Diets

Linted and delinted whole cottonseed, provided by Buckeye Technologies (Memphis, TN), originated from the same source and differed only in that delinted seed was mechanically delinted. All cottonseed used during both blocks was delivered at the beginning of the trial.

The diet fed during the pretrial period contained a 50:50 blend of linted and delinted WCS (Table 1). Rations were formulated according to NRC (2001) recommendations. Treatment diets were identical except for the WCS source (Table 1).

Table 1. Diet ingredients for each treatment.

	Pretrial period	Treatment diets	
		DWCS[1]	LWCS[2]
	% DM		
Corn silage	28.1	28.1	28.1
Alfalfa silage	23.0	23.0	23.0
High moisture shelled corn	27.8	27.8	27.8
Linted whole cottonseed	6.5	0.0	13.0
Delinted whole cottonseed	6.5	13.0	0.0
Soybean meal (48% CP)	1.8	1.8	1.8
Expeller soybean meal[3]	1.8	1.8	1.8
Blood meal	2.0	2.0	2.0
Salt (NaCl)	0.3	0.3	0.3
Limestone	1.0	1.0	1.0
Dicalcium-phosphate	0.4	0.4	0.4
Sodium bicarbonate	0.7	0.7	0.7
Vitamin-mineral supplement[4]	0.1	0.1	0.1

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]Soyplus, West Central Cooperative, Ralston, IA.

[4]Vitamin-mineral supplement: 19.4% Ca, 5.51% S, 6.2×10^3 mg/kg of Zn, 5.1×10^3 mg/kg of Mn, 2.4×10^3 mg/kg of Fe, 1.3×10^3 mg/kg of Cu, 43.1 mg/kg of Co, 320 mg/kg of Se, 7.1×10^6 IU/kg vitamin A, 2.2×10^6 IU/kg vitamin D, and 1.8×10^6 IU/kg vitamin E.

Sampling, Laboratory Analyses, and Calculations

Feeds offered and refused were weighed daily from the beginning of the pretrial period until the end of the experimental period of each block. Samples of TMR, feed refusals, and alfalfa and corn silages were collected daily, stored frozen, and subsampled weekly. Concentrates were sampled weekly. Feed samples were dried at 60°C for 48 h every week. Forages were ground to 1 mm and concentrates to 2 mm in a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Samples of WCS were kept frozen and ground through a 2-mm diameter screen before thawing at the end of the experiment. Ground concentrates were composited monthly and ground through a 1-mm screen in the Wiley mill. All feeds were analyzed at the end of the experiment for CP, neutral detergent fiber, and acid detergent fiber. Feed intake was calculated weekly based on measured DM content of frozen TMR and feed refusals.

Fresh samples of alfalfa and corn silage were collected weekly. A portion of these samples (~0.5 kg) was used to determine DM content, and, along with measurements of DM of high moisture shelled corn, was used to make weekly adjustments of the diets.

Crude protein was determined by a combustion method, according to AOAC (1990), in a LECO FP-2000 Nitrogen/Protein Analyzer (Leco Co., St. Joseph, MI). Fiber was analyzed in an Ankom^{200} Fiber Analyzer (Ankom Technology, Fairport, NY), according to the sequential NDF/ADF analysis utilizing heat-stable amylase and sodium sulfite (Van Soest et al., 1991). Feed samples were composited by block and analyzed according to AOAC (1990) by Dairyland Laboratories Inc. (Arcadia, WI) for ether extract.

Milk production was recorded daily from each milking and averaged weekly for statistical analyses. Milk was sampled every 2 wk from a.m. and p.m. consecutive milkings. Milk samples were sent to the AgSource Cooperative Service (Menomonie, WI) for analyses of fat, true protein, lactose, and SNF by near-infrared spectroscopy (Foss MilkoScan 4000; Foss Technology, Eden Prairie, MN), and for somatic cells by fluorescence (Fossomatic 5000; Foss Technology). Milk components were weighted based on a.m. and p.m. milk production on sampling date. The milk components measured, combined with average milk production for the week preceding and the week following test day, were used to calculate 3.5% FCM and energy-corrected milk (Tyrrell and Reid, 1965).

Approximately 900 g of feces, split between an a.m. and p.m. sampling, was obtained from each cow during wk 3 and 13 of the experimental periods to measure the concentration of intact seeds in the feces. A portion of each a.m. and p.m. sample (~300 g) was composited and frozen for at least 1 wk before being wet-sieved through a set of three screens (maximum openings of 10.16, 4.35, and 3.07 mm). Subsamples (150 g) were analyzed for DM content individually from a.m. and p.m. samplings. Recovered intact seeds from the feces of each cow were composited by treatment and sampling date. Composited samples were ground through 1-mm screen in a Wiley mill and analyzed for CP, NDF, and ADF contents.

Apparent DM digestibility of the two treatment diets was measured with only half of the cows and for samples obtained from only one of the two sampling weeks in each period. Apparent digestibility of diet DM and fecal output were estimated using indigestible ADF as an internal marker (Cochran et al., 1986) in fecal samples collected from 40 randomly selected cows by parity, treatment, and block (10 cows per treatment per parity; 14 and 6 multiparous, and 12 and 8 primiparous cows from blocks I and II, respectively). Fecal and feed samples used to estimate DM digestibility were collected during the last fecal sampling from each block and incubated in duplicate in the rumen of a cow for 12 d to determine indigestible ADF. Fecal excretion of intact seeds was calculated based on DM digestibility values obtained with these 40 cows.

Body condition score (1 = thin to 5 = fat) was determined by two different evaluators, according to Wildman et al. (1982). Cow weights were averaged after they were measured for 2 consecutive days after the p.m. milking at the beginning and end of each experimental period.

Statistical Analyses

Statistical analyses were performed using MIXED procedures of SAS 8.0 (SAS, 1999) for randomized complete block design with two treatments in two blocks. The model set to test the effect of different WCS sources on performance of lactating cows included covariate, treatment, week, and treatment × week interaction. The random statement had cow and block. Statistical analyses of the complete dataset initially included parity, parity × week, and parity × treatment interactions in the model. Interactions were significant only for changes in BCS and percentage of seeds excreted in feces (DM basis). Therefore, the dataset was split, and primiparous cows were analyzed separately from multiparous cows using covariate adjustments for DMI, milk yield, milk composition, BW, and BCS. The results are presented separately by parity. Intake, milk yield, milk composition, and intact whole cottonseed excretion data were averaged weekly and analyzed as repeated measures within cow. Interactions, when significant, are discussed in the text. First-order autoregressive covariate structure was chosen based on the Akaike's information criterion. Statistical analyses of estimated DM digestibility, fecal excretion, and seed excretion in grams and as a proportion of seed intake included data from the 40 cows randomly selected from the original dataset and did not include a covariate in the model.

RESULTS AND DISCUSSION

Lint contents of DWCS and LWCS were 3.7 and 11.7%, respectively, and were within the typical range of measured amounts (Smith and Cothren, 1999). Delinted WCS was higher in CP and ether extract, and lower in NDF and ADF than LWCS (Table 2). There was more variability in the chemical analysis of DWCS than for LWCS. Nutrient composition of LWCS used in the experiment was similar to that reported elsewhere (Bernard and Calhoun, 1997; NRC, 2001; Harvatine et al., 2002a). Pima cottonseed, a naturally delinted cottonseed, was 17% higher in CP, 26% lower in NDF, and 20% lower in ADF than whole linted Upland cottonseed (Santos et al., 2002). Despite the differences in chemical composition between LWCS and DWCS, treatment diets did not measurably differ in their nutrient composition (Table 3). The presence of more lint in LWCS than in DWCS (11.7 vs. 3.7%) dilutes protein and oil content of LWCS, but since the diets contained only 13% cottonseed, this modest difference in protein

Table 2. Chemical composition of forages and whole cottonseeds.

	DM	CP	NDF	ADF	EE[1]
	- % (SD) -	% DM (SD)			
Alfalfa silage	40.8 (6.79)	22.1 (1.27)	38.8 (4.13)	30.6 (4.20)	2.98 (0.51)
Corn silage	36.8 (5.62)	7.2 (0.52)	39.0 (3.21)	21.0 (1.77)	3.02 (0.14)
Linted WCS[2]	92.3 (0.90)	22.4 (0.94)	51.1 (1.55)	36.0 (1.47)	18.2 (0.12)
Delinted WCS[2]	91.6 (1.28)	24.0 (1.69)	47.0 (3.56)	29.4 (2.27)	21.0 (0.45)

[1]EE = Ether extract.

[2]WCS = Whole cottonseed.

and fat content is further diluted to a level at which sampling and analytical variance will render undetectable differences.

Dry matter intake, expressed in absolute terms or as a percentage of BW, was not different for the two treatments (Table 4). Multiparous and primiparous cows fed DWCS had similar milk yield, 3.5% FCM, and energy-corrected milk to those fed LWCS (Table 4). There were no significant differences in yield or concentration of milk fat, protein, lactose, or SNF (Table 5). These results are consistent with other studies evaluating whole or cracked Pima cottonseed in comparison with LWCS (Sullivan et al., 1993a, 1993b; Santos et al., 2002). Some measurements presented in Table 4, all related to DMI, showed significant interactions between treatment and week. These interactions could not be explained as trends over time but were likely related to sudden changes in ambient temperature.

It has been indicated that NDF in LWCS can partially replace forage NDF in diets with lower NFC (Mooney and Allen, 1997; Slater et al., 2000; Firkins et al., 2002; Harvatine et al., 2002a, 2002b). Although estimated dietary NFC was approximately 43% in our trial, TMR content of forage NDF was relatively high (19.9% DM). This may have overshadowed any possible effect lint removal could have had on cow performance. Also, differences in other nutrient contents between WCS sources were narrow, which limited detection of treatment differences.

Body weight and BCS were not affected by lint content of whole cottonseed in multiparous cows (Table 4). Primiparous cows on both treatments had similar ($P \leq 0.11$) BCS and BW at the end of the experiment. When initially analyzed together, significant parity × treatment interaction ($P \leq 0.03$) indicated that primiparous cows fed DWCS diet gained more BCS than those on LWCS, whereas multiparous cows were not affected by diet. Considerable variation in initial BW of primiparous cows increased the error (SEM = 46.1), which could have limited our ability to detect statistically significant differences.

All intact seeds in the feces were recovered with tweezers from the middle screen (4.35-mm maximum individual opening) for both WCS sources. It appeared that more hulls (not measured) were found on the lower screen (3.07-mm maximum individual opening) for DWCS. The concentration of intact WCS in feces was significantly greater with DWCS than for LWCS for multiparous and primiparous cows (Table 6), but the difference between treatments was larger in the second sampling with multiparous cows, as indicated by the significant ($P \leq 0.01$) interaction between WCS source and week of sampling. Multiparous cows excreted more delinted WCS as a proportion of fecal DM than primiparous cows (parity × treatment interaction; $P \leq 0.02$).

Seeds recovered from feces and analyzed for CP, NDF, and ADF were very similar in composition to seeds incorporated in the diet, indicating that the integrity of the seed coat was not damaged. Crude protein, NDF, and ADF contents for fecal LWCS and DWCS were: 21.8, 50.6, and 34.6%, and 22.9, 45.3, and 29.2%.

Dry matter digestibility of the TMR was measured for only 40 of the cows (Table 7) and averaged 63.6 for

Table 3. Chemical composition of pre-trial and experimental diets.

	Pretrial period	Treatment diets: DWCS[1]	Treatment diets: LWCS[2]
DM % (SD)	57.5 (0.04)	59.2 (1.82)	59.3 (1.76)
NE_L[3], Mcal/kg DM	1.63	1.64	1.62
	% DM (SD)		
CP	16.5 (0.05)	16.3 (0.02)	16.2 (0.12)
NDF	29.8 (0.19)	28.9 (0.76)	29.2 (0.71)
Forage NDF	20.8 (0.23)	19.8 (0.84)	19.8 (0.84)
ADF	18.6 (0.27)	17.6 (0.56)	18.4 (0.57)
Ether extract	5.23 (0.21)	5.40 (0.11)	5.05 (0.06)
NFC[3,4]	43.4	43.2	43.6
Ca[3]	0.94	0.94	0.94
P[3]	0.39	0.39	0.39

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]NE_L, NFC, Ca, and P were calculated based on NRC (2001) tabular values for individual feedstuffs.

[4]NFC = Nonfiber carbohydrate.

Table 4. Performance of dairy cows fed TMR containing either mechanically delinted whole cottonseed or linted whole cottonseed.

	Treatments			$P \leq$[3]		
	DWCS[1]	LWCS[2]	SEM	L	W	L*W
			Multiparous			
DMI (kg/d)	23.8	23.1	1.60	0.14	0.001	0.001
DMI (% BW)	3.76	3.73	0.26	0.73	0.001	0.001
Milk Yield (kg/d)	37.4	37.5	0.83	0.91	0.001	0.68
3.5% FCM[4] (kg/d)	35.0	34.8	2.01	0.92	0.001	0.82
ECM[5] (kg/d)	32.2	32.0	1.69	0.84	0.001	0.96
Milk yield/DMI (kg/kg)	1.58	1.62	0.07	0.42	0.001	0.001
3.5% FCM[4]/DMI (kg/kg)	1.48	1.47	0.04	0.85	0.001	0.001
ECM[5]/DMI (kg/kg)	1.35	1.36	0.03	0.98	0.001	0.001
Body weight (kg)	636	629	9.29	0.58	—	—
BW change (kg/period)	30.2	26.0	9.87	0.76	—	—
BCS[6] (1-5)	3.06	3.11	0.05	0.53	—	—
BCS change	0.27	0.31	0.05	0.54	—	—
			Primiparous			
DMI (kg/d)	20.5	20.4	0.59	0.83	0.001	0.001
DMI (% BW)	3.46	3.52	0.29	0.64	0.001	0.001
Milk Yield (kg/d)	32.7	32.8	0.78	0.88	0.001	0.96
3.5% FCM[4] (kg/d)	31.3	30.9	1.12	0.70	0.001	0.11
ECM[5] (kg/d)	29.7	29.0	0.97	0.44	0.001	0.16
Milk yield/DMI (kg/kg)	1.62	1.62	0.05	0.89	0.001	0.001
3.5%FCM[4]/DMI (kg/kg)	1.53	1.52	0.03	0.68	0.001	0.001
ECM[5]/DMI (kg/kg)	1.46	1.42	0.03	0.40	0.001	0.001
Body weight (kg)	602	592	46.1	0.61	—	—
BW change (kg/period)	2.00	−9.60	133.0	0.60	—	—
BCS[6] (1-5)	3.16	3.05	0.44	0.11	—	—
BCS change	0.22	0.11	0.45	0.11	—	—

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]L = Main effect of lint; W = main effect of week; and L*W = interaction between lint and week.

[4]3.5% FCM = (0.432 × milk yield) + (16.2 × fat yield).

[5]ECM = 12.3 × (fat yield) + 6.56 × (SNF yield) − 0.0752 × (milk yield).

[6]BCS = Body condition score, according to Wildman et al. (1982).

DWCS and 64.8% for LWCS. Comparisons of digestibility between LWCS and mechanically DWCS were not found in the literature, but there is no indication that Pima cottonseed or acid delinted cottonseed or linted cottonseed had an effect on dietary DM or OM digestibility (Coppock et al., 1985; Sullivan et al., 1993a, 1993b; Zinn, 1995). After combining results from both primiparous and multiparous cows, only 2.5 and 1.5% of ingested seeds were excreted as undigested seeds with DWCS and LWCS, respectively (Table 7). Coppock et al. (1985) and Sullivan et al. (1993a, 1993b) showed that about 11 to 12% of acid delinted WCS appeared in the feces, whereas only 0.4 to 6% of LWCS was excreted in the feces. However, Zinn (1995) found that steers fed Pima cottonseed at 15% of diet DM excreted only 1.5% of the seeds intact in the feces. In the present experiment, we found 1.0 percentage unit greater excretion of intact seeds with DWCS than LWCS. Harvatine et al. (2002b) suggested that LWCS has a relatively long residence time in the rumen because lint entangles with large digesta particles, thus delaying passage of the linted seeds out of the rumen. Longer retention times in the rumen would likely decrease the amount of whole seeds reaching the feces. Therefore, mechanically delinted WCS may contain sufficient residual lint relative to acid delinted cottonseed to have a longer residence time in the rumen.

Given the small difference in passage of intact cottonseeds to feces for the two cottonseed sources in this experiment, one might consider feeding an amount of mechanically DWCS that would provide the same amount of digestible oil and protein as linted cottonseed would provide. Considering the dilution of lint (11.7 and 3.7%) and the slightly lower fecal excretion of intact seeds (1.5 and 2.5%) for LWCS than DWCS, respectively, it can be calculated that 0.91 kg of mechanically DWCS is equivalent to 1.0 kg of LWCS in terms of providing potentially digestible protein and oil. This does not consider the caloric value of digested lint. Lint is potentially very digestible (Palmquist, 1995), but it is slowly digested. Recognizing the caloric value of digestible lint, and considering that oil and

Table 5. Milk composition of dairy cows fed TMR containing either mechanically delinted whole cottonseed or linted whole cottonseed.

	Treatments			$P \leq$[3]		
	DWCS[1]	LWCS[2]	SEM	L	W	L*W
			Multiparous			
Fat, %	3.16	3.16	0.23	0.95	0.001	0.51
True protein, %	2.90	2.88	0.03	0.64	0.001	0.59
Lactose, %	4.76	4.74	0.03	0.58	0.001	0.88
Solids nonfat, %	8.54	8.51	0.06	0.44	0.001	0.83
Fat, kg/d	1.17	1.15	0.11	0.84	0.001	0.88
True protein, kg/d	1.06	1.06	0.03	0.87	0.001	0.71
Lactose, kg/d	1.77	1.76	0.04	0.88	0.001	0.86
Solids nonfat, kg/d	3.16	3.15	0.08	0.91	0.001	0.85
			Primiparous			
Fat, %	3.23	3.19	0.11	0.77	0.001	0.37
True protein, %	2.99	2.95	0.03	0.35	0.001	0.32
Lactose, %	4.98	5.02	0.05	0.19	0.09	0.76
Solids nonfat, %	8.88	8.88	0.04	0.99	0.001	0.69
Fat, kg/d	1.06	1.03	0.06	0.47	0.001	0.38
True protein, kg/d	0.98	0.95	0.02	0.18	0.11	0.81
Lactose, kg/d	1.65	1.63	0.04	0.65	0.01	0.84
Solids nonfat, kg/d	2.93	2.88	0.06	0.43	0.39	0.95

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]L = Main effect of lint; W = main effect of week; and L*W = interaction between lint and week.

protein have more economic value than digestible cellulose in lint, one might consider that 0.95 kg of mechanically DWCS is approximately equivalent to 1.0 kg of LWCS. Such discussion assumes that mechanically DWCS has sufficient residual lint, so behavior of the mechanically delinted seed in the rumen is not appreciably altered from that of LWCS. The key question is whether mechanically DWCS has all of the attributes of LWCS, except that it has less lint to contribute towards digestible calories. Better handling characteristics and greater density of protein and oil are positive features of mechanically DWCS, but more research is needed to accurately establish the amount of mechanically DWCS that will provide an amount of digestible nutrients equivalent to a given quantity of LWCS.

The small difference in fecal excretion of whole seeds between mechanically DWCS and LWCS in our study, coupled with similar milk production between treatment groups, does not support the NRC (2001) general suggestion that linted cottonseed should have 10% more energy available than delinted whole cottonseed.

CONCLUSIONS

Mechanically DWCS and LWCS performed similarly in lactation diets in this experiment. Lint removal does

Table 6. Proportion of intact cottonseed in fecal DM from dairy cows fed TMR containing either mechanically delinted cottonseed or linted cottonseed.

	DWCS[1]		LWCS[2]			$P \leq$[3]		
	wk 3	wk 13	wk 3	wk 13	SEM	L	W	L*W
				Multiparous				
n	20	20	20	20				
Intact WCS, % fecal DM	1.38	1.68	0.88	0.56	0.17	0.001	0.92	0.01
				Primiparous				
n	20	20	20	20				
Intact WCS, % fecal DM	0.99	1.06	0.63	0.59	0.13	0.01	0.90	0.65

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]L = Main effect of lint; W = main effect of week; and L*W = interaction between lint and week.

[4]Proportion of intact WCS in fecal DM was determined in 80 cows.

Table 7. Dry matter digestibility of the TMR and excretion of intact cottonseed from dairy cows fed TMR containing either mechanically delinted cottonseed or linted cottonseed.

	Treatments			$P \leq$[3]
	DWCS[1]	LWCS[2]	SEM	L
Multiparous				
n[4]	10	10		
DMI (kg/d)	21.9	24.2	1.98	0.11
WCS[5] consumed (kg/d)	2.85	3.14	0.26	0.11
DM digestibility of the TMR (%)	63.1	64.2	1.69	0.46
Fecal DM (kg/d)	8.06	8.67	1.05	0.33
Intact seed excreted (g/d)	93.1	64.6	16.0	0.22
Intact seed excreted, % WCS[5] consumed	3.1	1.9	0.46	0.06
Primiparous				
n[4]	10	10		
DMI (kg/d)	19.6	20.2	0.97	0.53
WCS[5] consumed (kg/d)	2.55	2.63	0.13	0.53
DM digestibility of the TMR (%)	64.1	65.5	0.82	0.24
Fecal DM (kg/d)	7.09	7.01	0.40	0.87
Intact seed excreted (g/d)	50.3	31.5	13.4	0.09
Intact seed excreted, % WCS[5] consumed	2.0	1.2	0.49	0.06

[1]DWCS = Diet containing mechanically delinted whole cottonseed.

[2]LWCS = Diet containing linted whole cottonseed.

[3]L = Main effect of lint.

[4]DM digestibility and cottonseed excretion were estimated from 40 cows.

[5]WCS = Whole cottonseed.

increase the concentration of protein and oil in the remaining seed, but this effect is diluted considerably when cottonseed makes up a small percentage of the total diet.

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